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EFFECT OF L-CARNITINE ADMINISTRATION ON ANATOMICAL STRUCTURE OF THE DIGESTIVE TRACT SEGMENTS IN LAMBS

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ABSTRACT

This study was conducted to evaluate the effect of oral administration of L-carnitine (LC) on the anatomical characteristics of various segments of the digestive tract in growing lambs. This study was carried out at Animal Experimental Station, belonging to the Animal Production Department, Faculty of Agriculture, Mansoura University, during the period from September to December 2014. A total of 9 Rahmani lambs (33.9±0.69 kg LBW and about 10 mo old) were assigned randomly into 3 groups according body weight. The three groups were assigned at random to receive 3 treatments. Animals in the 1st group (G1) were fed the control diet (14.5% CP and 10% CF). Lambs in the 2nd and 3rd groups were fed the same diet, but orally treated with LC at levels of 350 (G2) and 700 (G2) mg/h/d for 63 days as treatment period, respectively. Lambs were fed berseem hay (14.6% CP and 38% CF) and concentrate feed mixture (14.4% CP and 4.5% CF). Amount of feeds were adjusted every 2 weeks to reach 1.5 kg hay and 1.2 kg CFM at the end of the experimental period. At the end of the experimental period (63 d), lambs in each group were slaughtered after 12 h of fasting. The carcass was opened and the digestive tract was immediately removed. The digestive tract was tied starting from the esophagus up to the anus to cut off each segment. Full, empty and contents weights or volumes as well as intestinal measurements of each segment were recorded. Results showed that full weight of reticulo-rumen (RR), omasum (OM), abomasums (AB), cecum (CM), colon-rectum (CR), total stomach compartments (TSC) and total digestive tract (TDT) tended to be reduced as affected by LC. Full weight of small intestine (SI) was higher (P<0.05) in G1 than in G3, but those in G2 did not differ than in G1 or G3. Full weight of cecum relative to TDT was lower (P<0.05) in G2 than in G3, and both did not differ from G1. Empty weight of rumen was lower (P<0.05) in G3 than in G1 and G2. Empty weight relative to TDT for all segments was not affected by LC. Contents weight of OM and SI was lower (P<0.05) in G2 and G3 than in G1 by about 33 and 35% and 24 and 35%, respectively. Contents weight of CM relative to TDT was the highest (P<0.05) in G3, moderate in G1 and the lowest in G2. Full, empty and contents weights of RR, OM and AB relative to TSC were not affected by LC. Only full volume of SI and empty volume of OM and reduced in G3 (P<0.05) and G2 (P>0.05) compared with G1, while contents volume was not affected by LC. There were insignificant differences among groups in full and empty volumes of all segments relative to TDT, while contents volume of OM relative to TDT increased in G3 (P<0.05) and G2 (P<0.05). Full, empty and contents volumes of all segments relative to TDT were not affected by LC. Length of CM decreased (P<0.05), beside reduction (P>0.05) in SI and CR length and consequently in the total intestinal length. Length of SI increased (P<0.05) relative to total length of the intestinal segments. There were insignificant differences in circumference of intestinal segments.

It was concluded that L-carnitine treatment led to some changes in the anatomical structure of lambs, in terms of reducing weight or volume of tissues or contents in reticulo-rumen and small intestine.

Keywords: Lambs, L-carnitine, digestive tract, fresh tissue weight, full, empty, contents weight, volume.

INTRODUCTION

Several metabolic changes occur in the rumen epithelium in concern with morphological development, including decreased glucose oxidation, increased VFA oxidation and increased production of ketone bodies from butyrate (Heitmann, *et al.,* 1987 and Baldwant, *et al.,* 1992). The mechanisms that are responsible for rumen development has not been completely characterized; however, solid feed consumption stimulates rumen morphological development (Warner and Flatt, 1964) The influence of food on the morphology of the rumen epithelium affects primarily the number and size of the papillae (Liebich *et al.,* 1987).The rumen is covered by a stratified squamous epithelium that consists of leaf like papillae, which greatly increase the absorptive surface area (Steven and Marshall, 1970).

Carnitine can be synthesized in the animal body from protein-bound lysine and methionine, being in the form of L-carnitine and D-carnitine, but biologically the active form is L-carnitine (Vaz and Wanders, 2002). L-carnitine (β-hydroxy-γ-trimethylammonium butyrate) is vitamin-like amino-acid as a polar natural compound (Groff and Gropper, 2000). It plays an important role, in the cellular detoxification (Arrigoni-Martelli and Caso, 2001) and in lipid metabolism by carrying long-chain fatty acids to the mitochondria for β-oxidation to produce ATP required for cell function (Hoppel, 2003) as well as it is also important as antioxidant for protection of the cell membranes against oxidative damages (Kalaiselvi and Panneerselvam, 1998).

Several studies indicated that dietary supplements of L-carnitine increased growth performance (Carlson *et al.,* 2007) by improving apparent digestibility of lipid, energy and fatty acids (La Count *et al.,* 1995) and enhancing digestibility of most nutrients and rumen fermentation (Sherief, 2014). The hypothesis is that changes in rumen fermentation may be related to differences in the anatomical and/or histological structure of the digestive tract of lambs fed L-carnitine diets. No studies are available on the anatomical and histological structure of the digestive tract in lambs.

Therefore, the present study is directed towards evaluating the effect of oral administration of two levels from L-carnitine (0. 350 and 700 mg/day) on the anatomical and histological characteristics of various parts of the digestive tract in growing lambs during an treatment period of 63 days) after weaning when raised under the same dietary and managerial conditions.

MATERIALS AND METHODS

The current study was carried out at Animal Experimental Station, belonging to the Animal Production Department, Faculty of Agriculture, Mansoura University, during the period from September to December 2014.

Animals:

A total of 9 Rahmani lambs (averaged 33.9±0.69 kg live body weight and about 10 mo old) was taken from the flock of El-Serw Station, belonging to Animal Production Research Institute. Animals were assigned into 3 groups according to LBW and age (3 animals in each).The groups were assigned at random to three treatments. Animals in the 1st group (G1) were fed the control diet without any treatments. In the 2nd and 3rd groups, animals were fed the same diet, but orally treated with L-carnitine at levels of 350 (G2) and 700 (G2) mg/h/d for 63 days as treatment period, respectively. All the experimental animals were kept in semi-open pens and kept under the same environmental and managerial conditions.

Feeding system:

Animals were fed in group on a basal diet including concentrate feed mixture (CFM), berseem hay (BH). The CFM contained 50% barely, 32% ground yellow corn, 15% soybean meal, 1% limestone, 1% vitamins and minerals and 1% common salt. Based on the chemical analysis, the basal ration contained 91.5% DM, 14.39% CP, 4.5% CF, 0.50% EE, 67.61% NFE and 4.50% ash, while BH contained 88.5% DM, 14.59% CP, 38% CF, 0.50% EE, 25.41% NFE and 10% ash.

Prior to the beginning of the experiment, lambs were fed with hay and concentrate feed mixture (CFM) *ad libitum* for at least 2 weeks, as an adaptation period. After that, lambs were fed on adjusted amount of hay (750 g/h) and CFM (750 g/h). Amount of feeds were adjusted 2 weeks to reach 1.5 kg hay and 1.2 kg CFM at the end of the experimental period for all groups (63 days).

Slaughter and sampling procedures:

All animals were slaughtered on the last day. On the day of slaughter, animals were fed their diets 2-3 hours before slaughter and their live body weights were recorded. Each animal was killed by severing its jugular veins. The carcass was opened and the digestive tract was immediately removed. The digestive tract was tied starting from the esophagus up to the anus. Then it was tied with tight loops between each of the esophagus, reticulo-rumen, omaso-abomasum, small intestine, cecum and colon-rectum successively, to cut off each segment. The digestive tract was placed on a blackboard divided into squares (5 x 5 cm) and photographed.

Post-mortem measurements:

Absolute weight of digestive tract segments:

Full (tissue and contents) and empty weight (cleaned fresh tissue weight) of each stomach compartments and the intestinal segments were recorded to the nearest, gram. Fresh weight of four ruminal samples each of 5 x 5 cm were cut from ventral, ventral blind, dorsal and dorsal blind sacs. The mucosal layer was separated manually from the muscular layer of each 5 x 5 cm samples. Both layers were weighed and the percentage of each of these layers from the total tissue weight of the rumen was calculated.

Physiological volume:

The physiological volume of stomach compartments (reticulo-rumen and omaso-abomasum) and the, intestinal segments (small Intestine, cecum and colon-rectum) were measured by the difference between the volume of- each part when filled with its content and its volume after emptying the contents. In other words, the physiological volume equals the volume of the contents for each part.

Anatomical measurements:

The anatomical volumes of the small intestine, cecum and colon-rectum were estimated in terms of length and average circumference of the intestinal segments. The average circumference was obtained at five loci along the small intestine and three loci along the length of each of cecum and colon-rectum, the segments were flat to measure its internal circumference at these loci avoiding any stretching during measuring.

Statistical analysis:

Data were statistically analyzed by the one way analysis of variance using the General Linear Model procedures of (SAS, 2004). Duncan multiple range test was used to test the differences among means (Duncan, 1955) at $P<0.05$.

RESULTS AND DISCUSION

Full weight of the digestive tract segments:

Results presented in Table (1) showed that full absolute weight of all digestive tract segments including reticulo-rumen, omasum, abomasums, small intestine, cecum, colon-rectum, total stomach compartments and total digestive tract tended to be reduced as affected by L-carnitine (LC) treatment. The differences were insignificant, except for small intestine, which was significantly (P<0.05) higher in G1 (control) than in G3, but those in G2 did not differ significantly than in G1 or G3.

These results indicated effect of high level administration of LC on significantly (P<0.05) reducing full weight of the small intestine from 1.313 kg in G1 to 1.075 kg in G3 and insignificantly to 1.162 kg in G2.

Table (1): Full absolute weight (kg) of different digestive tract segments of lambs in the experimental groups.

Digestive tract segment	Full absolute weight (kg)			SEM
	Control (G1)	350 mg LC (G2)	700 mg LC (G3)	
Reticulo-rumen	5.188	4.779	3.733	0.541
Omasum	0.359	0.278	0.285	0.020
Abomasum	0.405	0.395	0.335	0.024
Total stomach	5.952	5.452	4.353	0.540
Small intestine	1.313^{a}	1.162^{ab}	1.075^{b}	0.051
Colon-rectum	1.144	1.030	0.898	0.088
Cecum	0.445	0.288	0.468	0.073
Total digestive tract	8.844	7.872	6.795	0.630

a and b: Means denoted within the same row with different superscripts are significantly different at P<0.05.

When full absolute weight of each segment was expressed as percentage of the total full weight of the digestive tract, results in Table (2) revealed that only relative full weight of cecum was significantly (P<0.05) affected by LC treatment, being significantly (P<0.05) lower in G2 than in G3, but relative full weight of cecum in both LC treatments did not differ significantly than that in the control (G1).

Table (2): Full weight of different digestive tract segments proportional to total weight of digestive tract of lambs in the experimental groups.

Digestive tract segment	Full weight as % of the total digestive tract			SEM
	Control (G1)	350 mg LC (G2)	700 mg LC (G3)	
Reticulo-rumen	58.51	60.08	54.70	2.49
Omasum	4.13	3.55	4.30	0.37
Abomasum	4.64	5.13	4.90	0.50
Small intestine	14.91	14.95	15.91	1.16
Cecum	4.93^{ab}	3.08^{b}	6.98^{a}	0.83
Colon-rectum	12.88	13.21	13.30	1.00

a and b: Means denoted within the same row with different superscripts are significantly different at P<0.05.

It is of interest to note that the differences in relative full weight of the small intestine were not significant despite the insignificant reduction in full absolute weight of this segment. This may suggest that full weight of the small intestine was not affected by LC administration. Also, such findings may indicate no effect was observed for LC on absolute or relative full weight of all digestive tract segments.

Generally, full weight as absolute or relative weights of the reticulo-rumen in all treatment groups represented the highest values among all digestive tract segments, ranging from 3.73 to 5.19 kg as absolute weight and from 54.70 to 60.08% as relative weight. However, omasum showed the lowest values (Tables 1 and 2).

Empty weight of the digestive tract segments:

Results presented in Table (3) showed that empty absolute weight of all digestive tract segments including reticulo-rumen, omasum, abomasums, small intestine, cecum, colon-rectum, total stomach compartments and total digestive tract tended to be reduced as affected by LC treatment at a level of 700 mg/h. The differences were insignificant, except for empty absolute eight of rumen, being significantly (P<0.05) lower in G3 than in G1 and G2.

These results indicated effect of high level administration of LC on reducing empty weight (fresh tissue weight of the rumen significantly (P<0.05) from 921.67 g in G1 to 725.0 g in G3.

Table (3): Empty weight (g) of different digestive tract segments of lambs in the experimental groups.

Digestive segment	Empty weight (g)			SEM
	Control (G1)	350 mg LC (G2)	700 mg LC (G3)	
Rumen	921.67[a]	908.07[a]	725.00[b]	40.32
Reticulum	128.60	121.93	117.77	14.74
Omasum	141.67	133.90	119.20	5.78
Abomasum	199.67	200.00	173.03	9.12
Total stomach	1391.6	1363.9	1135	42.28
Small intestine	808.33	833.33	748.33	29.84
Cecum	57.33	47.43	56.60	4.75
Colon-rectum	550.00	536.67	501.67	42.32
Total digestive tract	2807.26	2781.33	2441.6	87.78

a and b: Means denoted within the same row with different superscripts are significantly different at P<0.05.

The ratio of the rumen weight to abomasum weight was found to be 0.3:l at birth, increased to 2.5:l by 50 days of age (Wardrop and Coomb, 1960). In 3 years old-Merino wethers ranging in their live body weight from 61.8 to 75.5 kg, (Purser and Moir, 1966) found that the fresh tissue weight (FTW) of the rumen ranged from 788 to 1186 g. Rumen weight may also differ between breeds of the same species, In this respect, (Khalil, 1974) found highly significant differences between sheep breeds (Ossimi, Rahmani and Merino) in FTW from birth to adult age. The growth rate of internal organs in sheep is influenced by weight and age of the animal and the plane of nutrition (Palsson and Verges, 1952). In this respect, (Warner *et al.,* 1956) reported that the consumption of roughages elicits an early increase in the growth of the stomach tissue. The empty stomach weight (FTW) was 1.22 kg in adult sheep (Walker and Walker, l96l and Khalil, 1974).

When absolute empty weight of each segment was expressed as percentage of the total empty weight of the digestive tract, results in Table (4) revealed insignificant differences in relative empty weight of all digestive tract segments among treatment groups.

Such results indicated some effect of LC at level of 350 mg/h on reducing the ruminal fresh tissue significantly ($P<0.05$) as absolute weight and insignificantly as a weight relative to weight of total fresh tissues of the digestive tract.

Generally, fresh tissue weight as absolute or relative weights of the reticulo-rumen in all treatment groups represented the highest values among all digestive tract segments, ranging from 725.0 to 921.67g as absolute weight and from 34.46 to 37.41% as relative weight. Values of the small intestine followed the reticulo-rume, while cecum showed the lowest values (Tables 3 and 4).

Table (4): Empty weight of different digestive tract segments proportional to total weight of the digestive tract of lambs in the experimental groups.

Digestive segment	Empty weight as % of TDT			SEM
	Control (G1)	350 mg LC (G2)	700 mg LC (G3)	
Reticulo-rumen	37.41	37.08	34.46	1.49
Omasum	5.00	4.82	4.89	0.35
Abomasum	7.11	7.18	7.09	0.22
Small intestine	28.79	29.93	30.69	0.62
Cecum	2.10	1.72	2.34	0.15
Colon-rectum	19.59	19.27	20.53	1.03

TDT: Total digestive tract

In sheep, weight of each segment of the digestive tract as a percentage of the its total weight in sheep was affected by age (Abdel-Khalek, 1986) and composition of the diet (Abdel-Khalek, et al. 2000 and Abo Ward, 2008). At early ages, the small intestine presents the heaviest part of the alimentary tract. With advance of age, however, the reticulo-rumen constitutes largest part of the digestive tract (Abdel-Khalek, 1986).

Contents weight of the digestive tract segments:

Results presented in Table (5) showed that contents absolute weight of all digestive tract segments including reticulo-rumen, omasum, abomasums, small intestine, cecum, colon-rectum, total stomach compartments and total digestive tract tended to be reduced as affected by both LC treatments. The differences were insignificant, except for weight of omasal and small intestinal contents, being significantly ($P<0.05$) lower in G2 and G3 than in G1 by about 33 and 35% and 24 and 35%, respectively.

These results indicated effect of LC administration on reducing contents weight of omasum and small intestine in G2 and G3.

When contents weight of each segment was expressed as percentage of the total contents weight of the digestive tract, results in Table (6) revealed insignificant differences in relative contents weight of all digestive tract segments among treatment groups, except for weight of cecal contents, being significantly ($P<0.05$) the highest in G3, moderate in G1 and the lowest in G2. It is of interest to note that relative contents weight of reticulo-rumen showed markedly higher values in G2 and slightly lower values in G3 than in G1, but the differences were not significant.

Table (5): Contents weight (kg) of different digestive tract segments in the experimental groups.

Digestive segment	Contents weight (kg)			SEM
	Control (G1)	350 mg LC (G2)	700 mg LC (G3)	
Rumino - reticulum	4.128	3.738	2.890	0.558
Omasum	0.217[a]	0.145[b]	0.165[b]	0.015
Abomasum	0.205	0.195	0.161	0.024
Total stomach	4.550	4.078	3.216	0.559
Small intestine	0.505a	0.328b	0.326b	0.031
Cecum	0.388	0.191	0.412	0.071
Colon- rectum	0.594	0.493	0.397	0.052
Total digestive tract	6.037	5.091	4.353	0.636

a and b: Means denoted within the same row with different superscripts are significantly different at P<0.05.

Table (6): Contents weight of different digestive tract segments proportional to total weight of the digestive tract of lambs in the experimental groups.

Digestive segment	Contents weight as % of TDT			SEM
	Control (G1)	350 mg LC (G2)	700 mg LC (G3)	
Reticulo-rumen	68.36	72.57	66.13	2.32
Omasum	3.69	2.94	3.75	0.42
Abomasum	3.51	4.03	3.63	0.65
Small intestine	8.39	6.67	7.69	1.04
Cecum	6.26[b]	3.90[c]	9.56[a]	1.21
Colon- rectum	9.79	9.89	9.24	0.82

a and b: Means denoted within the same row with different superscripts are significantly different at P<0.05. TDT: Total digestive tract.

These findings indicated pronounced effect (P>0.05) of LC at level of 350 mg/h on increasing relative contents weight of reticulo-rumen and significant (P<0.05) effect of LC at a level of 700 mg/h/d on increasing relative contents weight of the cecum.

Generally, contents weight as absolute or relative weights of the reticulo-rumen showed the highest percentage of total contents weight of the digestive tract in all groups, ranging from 2.890 kg in G3 to 4.128 kg in G1 as absolute weight and from 66.13% in G3 to 72.57% in G2 as relative weight (Tables 5 and 6).

Full, empty and contents weights of stomach compartments relative to its total weight:

Results in Table (7) revealed that when full, empty and contents weights of reticulo-rumen were expressed as percentages of total weights of stomach compartments no pronounced effect of LC treatment on all relative weights, but contents weight of the reticulo-rumen relative to total stomach compartments was the highest (about 90%), while that of empty weight was the lowest (about 65%). On the other hand, full, empty and contents weights of omasum decreased and of abomasum increased slightly only in G2. These differences did not reach to the level of significance in relation to limited number of animals in each group (n=3).

Table (7): Full, empty and contents weights of different stomach compartments of lambs proportional to its total values in the experimental groups.

Stomach compartment	As percentage of total stomach compartment			SEM
	Control (G1)	350 mg LC (G2)	700 mg LC (G3)	
Full weight (%):				
Reticulo-rumen	87.00	87.25	85.70	1.21
Omasum	6.10	5.20	6.70	0.67
Abomasum	6.90	7.55	7.66	0.86
Empty weight (%):				
Rumen	66.15	66.58	63.97	1.36
Reticulum	9.310	8.94	10.24	0.98
Omasum	10.17	9.79	10.53	0.71
Abomasum	14.37	14.69	15.26	0.72
Content weight (%):				
Reticulo-rumen	90.51	91.13	89.96	1.03
Omasum	4.87	3.71	5.13	0.66
Abomasum	4.62	5.16	4.91	0.86

With respect to age, Wardrop and Coomb (1960) found that the rumen had the fastest growth rate of stomach compartments (42.3 times to its weight), followed by the reticulum (20.6 times),omasum (11.8 times) and abomasum (5.7 times) in Merino lambs from birth up to 16 weeks of age. Similar results were obtained by Khalil (1974) on several breeds of sheep and by Abdel-Khalek (1986) on sheep and goats.

In comparing the growth rate of the intestinal segments with stomach compartments, Wardrop and Coomb (1960) found that the small intestine presents the greatest weight as a percentage of total weight of the intestine, while the cecum has the smallest value. The data obtained by Khalil (1974) showed that the percentage of small intestine weight relative to the total intestinal weight declined with advancing age from birth to 12 months of age, whereas that of colon increased and that of cecum remained constant.

Full volume of the digestive tract segments:

Results presented in Table (8) showed that full volume of all digestive tract segments including reticulo-rumen, omasum, abomasums, cecum, colon-rectum, total stomach compartments and total digestive tract tended was not affected significantly by LC treatment, although there was a tendency of reducing full volume of these segments in G2 and G3 as compared to G1. However, only full volume of the small intestine was significantly ($P<0.05$) reduced in G3 and insignificantly in G2.

These results indicated that full volume was affected by high level administration of LC, reflecting marked reduction in full volume of the small intestine being significantly ($P<0.05$) from 1496.6 ml in G1 to 983.3 ml in G3 and insignificantly to 1113.3 ml in G2.

Table (8): Full volume (ml) of different digestive tract segments of lambs in the experimental groups.

Digestive segment	Full volume (ml)			SEM
	Control (G1)	350 mg LC (G2)	700 mg LC (G3)	
Reticulo-rumen	5200.0	4833.3	3833.3	528.44
Omasum	316.6	323.3	293.3	293.33
Abomasum	316.6	416.6	358.3	29.26
Total stomach	5833.3	5573.3	4485.0	544.89
Small intestine	1496.6[a]	1133.3[ab]	983.3[b]	111.69
Cecum	383.3	333.3	483.3	57.73
Colon- rectum	1300.0	1093.3	816.6	244.10
Total digestive tract	9013.3	8133.3	6768.3	671.09

a and b: Means denoted within the same row with different superscripts are significantly different at P<0.05.

When full volume of each segment was expressed as percentage of the total full volume of the digestive tract, results in Table (9) revealed insignificant differences among the experimental groups, although full volume of omasum, abomasums and cecum relative to full volume of the digestive tract were slightly higher in G3 than in G1 and G2. As for full weights, reticulo-rumen showed the highest full volume relative to the total digestive tract.

Table (9): Full volume of different digestive tract segments proportional to total volume of the digestive tract of lambs in the experimental groups.

Digestive segment	Full volume as % of TDT			SEM
	Control (G1)	350 mg LC (G2)	700 mg LC (G3)	
Reticulo-rumen	57.69	59.07	56.56	2.50
Omasum	3.58	3.94	4.23	0.18
Abomasum	3.54	5.18	5.27	0.47
Small intestine	16.74	14.10	14.69	1.85
Cecum	4.28	4.15	7.26	0.97
Colon-rectum	14.17	13.57	11.99	2.22

TDT: Total digestive tract.

Empty volume of the digestive tract segments:

Results presented in Table (10) showed that empty volume (tissue volume) of all digestive tract segments including reticulo-rumen, abomasums, cecum, total stomach compartments and total digestive tract tended were not significantly affected by LC treatment, although there was a tendency of reducing empty volume of these segments in G2 and G3 as compared to G1. However, empty volumes of omasum and colon-rectum were significantly (P<0.05) reduced in G3 and insignificantly in G2.

These results indicated that high level administration of LC significantly (P<0.05) reduced in the tissue volume of the omasum and colon –rectum in G3 and insignificantly in G2.

Table (10): Empty volume (ml) of different digestive tract segments of lambs in the experimental groups.

Digestive segment	Empty volume (ml)			SEM
	Control (G1)	350 mg LC (G2)	700 mg LC (G3)	
Reticulo-rumen	1016.6	1016.6	950.0	48.11
Omasum	145.0[a]	130.0[ab]	113.3[b]	5.61
Abomasum	206.6	200.0	190.0	9.32
Total stomach	1368.3	1346.6	1253.3	46.19
Small intestine	866.6	703.3	650.0	159.44
Cecum	61.6	54.0	50.0	7.31
Colon-rectum	533.3[a]	503.3[ab]	433.3[b]	20.27
Total digestive tract	2830.0	2607.3	2386.6	215.77

a and b: Means denoted within the same row with different superscripts are significantly different at P<0.05.

When empty volume of each segment was expressed as percentage of the total empty volume of the digestive tract, results in Table (11) revealed insignificant differences among the experimental groups, although empty volume of reticulo-rumen and abomasums tended to increase, while of the small intestine decreased relative to empty volume of the digestive tract as affected by LC treatment. In comparing with full volume, empty volumes of reticulo-rumen and the small intestine showed the highest empty volume relative to the total digestive tract.

Table (11): Empty volume of different digestive tract segments proportional to total volume of digestive tract of lambs in the experimental groups.

Digestive segment	Empty volume as % of TDT			SEM
	Control (G1)	350 mg LC (G2)	700 mg LC (G3)	
Reticulo-rumen	36.06	39.41	39.99	2.00
Omasum	5.18	5.19	4.74	0.59
Abomasum	7.36	7.83	7.99	0.74
Small intestine	30.13	25.71	27.07	4.12
Cecum	2.15	2.12	2.08	0.17
Colon- rectum	19.12	19.75	18.13	1.27

TDT: Total digestive tract.

Contents volume of the digestive tract segments:

Results presented in Table (12) showed insignificant effect of LC treatment on contents volume of all digestive tract segments including reticulo-rumen, abomasums, omasum, small intestine cecum, total stomach compartments and total digestive tract. However, contents volume of reticulo-rumen, small intestine, colon-rectum and total stomach tended to be reduced, while contents volume of omasum and abomasums increased in G2 and G3 as compared to G1. These reduction in most segments resulted in reducing contents volume of the whole digestive tract.

Fermentation within the digestive tract of ruminants needs voluminous capacity of stomach or large intestine. In male Merino lambs, Walker and Walker (1961) found that the volume of rumen liquor was 110 ml at 35 days of age, while in Merino wethers (over one year old), it ranged between 854 and l539 ml. **(Church *et al.,* 1962)** observed a rumen volume of 969 ml at 4 weeks and 1461 at 40 days of age.

Table (12): Contents volume (ml) of different digestive tract segments of lambs in the experimental group.

Digestive segment	Contents volume (ml)			SEM
	Control (G1)	350 mg LC (G2)	700 mg LC (G3)	
Reticulo-rumen	4183.3	3816.6	2883.3	573.08
Omasum	171.6	193.3	180.0	21.27
Abomasum	110.0	216.6	168.33	30.64
Total stomach	4465.0	4226.6	3231.6	587.86
Small intestine	630.0	430.0	333.3	115.19
Cecum	321.6	279.3	433.3	62.85
Colon-rectum	766.6	590.0	383.3	230.24
Total digestive tract	6183.3	5526.0	4381.6	803.43

The size of the fore stomach increased with consumption of plant material, and proportions similar to that in adult goats were obtained at seven months of age by using x-ray procedures (Trautmann and Fiebiger, 1957). In 3-years Merino wethers fed semi-purified ration and weighed from 61.8 to 75.5 kg, Purser and Moir (1966) found that the rumen volume estimated by marker technique ranged between 3.81 and 9.88 liters, while volume of the rumen contents ranged from 2.52 to 2.65 liters. In cannulated Merino sheep weighing from 13.0 to 34.2 kg, volume of the rumen fluid ranged between 2.86 and 6.25 liters with different types of feeds (Leng and Brett, 1966), while using four merino rams of 60 kg live weight, Antoniewicz and Pisulenwski (1982) found that the mean volume estimated with polyethylene glycol (PEG) introduced 1.5 h after feeding, ranged between 8.3 and 10.7 liters. In cannulated crossbred rams (average weight 61 Kg), fed on diet containing 60% concentrate and different levels of selinomycin, the rumen volume ranged from 5.3 to 6.4 liters (Merchen and Berger, l985).

Regarding the physiological volume of intestinal segments, (Khalil, 1974) found that it was 32-62, 10-20 and 19-23 ml in small intestine, cecum and colon at birth, respectively. In adult sheep, Breasile (1971) and Frandson (1981) reported that the cecum volume was about one liter.

Capacity of stomach compartments varies with species, breed, feed intake, nature of diet and body weight. (Benzie and Phillipson, 1957) found in their studies on stomach development in kids and lambs at birth that the omaso-abomasum capacity was large in comparison to the reticulo-rumen both species, thereafter the latter organs developed relatively more rapidly.

With respect to age, Khalil (1974) found that capacity of reticulo-rumen and omaso-abomasum in several breeds of lambs, was 60 - 70 and 210 - 450 ml at birth. The reticulo-rumen showed a great development with age, the age of 2.5 months was very important for the final development of the omaso-abomasum.

Capacity of the rumen varies with body weight. In Merino wethers which weighed between 61.8 and 75.5, kg, Purser and Moir (1966) found that the rumen capacity ranged from 9.9 to 24.0 liters. In adult sheep, Bhattacharya (l980) found that capacity of omasum and abomasum was 0.55 and 2.04 liters, respectively. However, capacity of the rumen was 18.5 liters in sheep weighed 38.8/kg, while reticulum capacity was 1.6 liters.

In various breeds of goats, Devendrs (1980) reported that the average capacity were 28.1, 2.3l, 1.21 and 4.1 liters in rumen, reticulum and abomasum, respectively.

When contents volume of each segment was expressed as percentage of the total volume of the digestive tract contents, results in Table (13) revealed only significant ($P<0.05$) differences among the experimental groups in contents volume of omasum, being significantly ($P<0.05$) lower in G3, but did not differ significantly from that in G2 and G1. It is worthy noting that contents volume of colon-rectum increased in both treatment groups (G2 and G3) as compared to G1, but the differences were not significant. As indicated for full volume, reticulo-rumen showed the highest contents volume relative to the whole volume of the digestive tract contents, ranging from 65.78 in G1 to 68.32 in G2.

Table (13): Contents volume of different digestive tract segments proportional to total weight of total content of digestive tract in the experimental groups.

Digestive segment	Contents volume as % of TDT			SEM
	Control (G1)	350 mg LC (G2)	700 mg LC (G3)	
Reticulo-rumen	65.78	68.32	67.86	2.49
Omasum	3.91[a]	3.47[ab]	2.94[b]	0.18
Abomasum	3.73	4.16	1.90	0.76
Small intestine	7.89	7.40	10.32	1.81
Cecum	10.21	5.35	5.27	1.71
Colon-rectum	8.48	11.3	11.71	3.19

a and b: Means denoted within the same row with different superscripts are significantly different at $P<0.05$. TDT: Total digestive tract.

From 4 months up to adult age, the percentage of physiological volume ranged between 75 and 80% for the reticulo-rumen, 3-9% for each of omaso-abomasum, small intestine and large intestine and about 3% for the cecum in several breeds of lambs (Khalil, l974). Similar values of the digestive tract proportions were reported in lambs (Randall, 1974).

Full, empty and contents volumes of stomach compartments relative to its total volume:

Results in Table (14) revealed a decrease in full and contents volume of reticulo-rumen beside an increase in its tissue volume as percentage of total volume of stomach compartments. However, omasum showed an opposite trend to reticulo-rumen. Yet, only full and contents volumes of colon-rectum relative to total volume of the stomach increased as affected by LC treatment on all relative weights, but the differences were not significant. Generally, reticulo-rumen showed the highest full, empty and contents weight relative to the whole volumes of the stomach.

The physiological volume of reticulo-rumen as a percentage of total volume of stomach increased to reach maximal volume (95%) at 2.5 months of age, while that of omaso-abomasum reach minimal volume (5%) at 2.5 months of age. In grazing goats aged 70-days, **Tamate (1957)** observed that the reticulo-rumen was about 85% of the total stomach volume at 50 -68 days of age.

Table (14): Full, empty and contents volumes of stomach compartments proportional to its total values.

Digestive segment	Experimental group			SEM
	Control (G1)	**350 mg LC (G2)**	**700 mg LC (G3)**	
Full volume:				
Rumino-reticulum	89.01	86.41	85.64	1.01
Omasum	5.53	5.82	6.38	0.25
Abomasum	5.46	7.77	7.98	0.91
Empty volume:				
Rumino-reticulum	74.25	75.4	75.77	1.14
Omasum	10.62	9.75	9.06	0.75
Abomasum	15.13	14.85	15.17	0.69
Contents volume:				
Rumino-reticulum	93.7	89.76	89.65	1.06
Omasum	3.80	4.66	5.31	0.35
Abomasum	2.50	5.58	5.04	0.99

In several breeds of sheep, the capacity of the different stomach compartments as percentage to total capacity was the highest in the rumen. At adult age, the reticulo-rumen represented about 80% or more of total capacity of stomach in both sheep (Habel, 1975; Bhattacharya, 1980 and Abdel-Khalek, 1986).

In different species, Louca *et al.,* (1982) reviewed the capacity of reticulo-rumen relative to the whole stomach was 73% in sheep, while the relative capacity of abomasum was 22%. By measuring water filling the different compartments, Bhattacharya (1980) found that relative proportions of rumen to total stomach volume was 81% in sheep.

Anatomical measurements of intestinal segments:

Results presented in Table (15) showed significant ($P<0.05$) decrease in length of cecum, beside insignificant reduction in length of the small intestine and colon-rectum and consequently in the total intestinal length. These results were followed by significant ($P<0.05$) increase in length of small intestine and significant ($P<0.05$) decrease in length of large intestine relative to total length of the intestinal segments.

Regarding circumference of the intestinal segments, there were insignificant differences in circumference of small intestine, cecum and colon-rectum, but all values tended to decrease in G2 and G3 as compared to G1 (Table 15).

Length and circumference of the intestinal segments vary within several breeds of sheep (Khalil, 1974) or in sheep and goats (Abdel-Khalek, 1986). The small intestine constitutes the greatest portion of total intestinal tract at all ages (Khalil, 1974 and Abdel-Khalek, 1986). Small intestine for weaned lambs fed solid feeds or milk ranged between 21.93 to 24.01 meter. In both groups the small intestine comprised a constant length (80%) relative to the total length. Increasing length of the small intestine may be a resultant effect to the solid feed administrated, which led to stretch its length (Abou Ward, 2008).

Table (15): length and relative length of small and large intestine as affected by experimental treatments.

Intestinal segment	Experimental group			SEM
	Control (G1)	350 mg LC (G2)	700 mg LC (G3)	
Segmental length:				
Small intestine (m)	25.40	22.48	23.60	1.497
Cecum (cm)	37.0a	28.3b	31.7b	1.10
Colon-rectum (m)	6.83	6.38	5.58	0.520
Total length of intestines (m)	32.23	28.87	29.18	1.98
Relative length of small intestine (%)*	78.89[ab]	77.89[b]	80.82[a]	0.56
Relative length of large intestine (%)	21.10ab	22.10a	19.17b	0.56
Segmental circumference (cm):				
Small intestines	3.9	2.5	2.5	0.49
Large intestine	5.1	3.7	4.5	0.50
Cecum	13.3	10.7	12.0	1.24

a and b: Means denoted within the same row with different superscripts Relative to total intestinal length are significantly different at P<0.05.

GENERAL DISCUSSION

Based on the obtained results, LC treatment, in particular at high level (700 mg/h/d) resulted in marked and significant ($P<0.05$) effects on the anatomical structure of the digestive tract segments especially, rumen, omasum, colon+rectum and small intestine. It is of interest to observe that the major target segment of the digestive tract to the effect of LC was small intestine. Pronounced effect was recorded for LC treatment on the anatomical structure of small intestine in term of reducing their full weigh, Full volume, contents weight and length. Also, omasum was affected by LC treatment in their contents weight, empty volume and contents volume relative to the whole contents volume of the digestive tract. On the other hand, empty weight (fresh tissue weight) as well as empty volume of colon+rectum were decreased as affected by LC treatment. Yet, all anatomical characteristics of most segments of the digestive tract were insignificantly reduced as affected by LC treatment.

Stomach of the ruminants is very large and it is composed of four compartments; rumen, reticulum, omasum and abomasum (Abdel-Khalek, 1986 and Dyce *et al.,* 2002). The rumen of the sheep occupies most of the left portion of the abdominal cavity and extends over the median plane in the middle and to some extent ventrally. Its long axis reaches from a point opposite the ventral part of the 8th inter-costal space or 9th rib almost to the pelvic inlet (May, 1970). The rumen is laterally compressed and extends from the abdominal roof to the floor and from left body wall across the midline, especially caudally and ventrally where it reaches the lower right flank (Dyce *et al.,* 2002). The rumen is partially divided internally into sacs by muscular pillars. The principal pillars encircle the organ dividing it into dorsal and ventral sacs, while lesser coronary pillars mark off the caudal ventral and dorsal blind sacs (Sisson and Grossman's, 1975 and Dyce *et al.,* 2002).

According to information in the literature, (Sherief, 2014) showed that digestion of nutrients significantly ($P<0.05$) improved by treatment of bulls with 1 or 2 g LC/h/d as compared to the controls. The pronounced effect was on increasing digestibility coefficients of CP and CF, while the lowest effect was on NFE. These findings indicated benefits of LC treatment at a level of 1 or 2 g /h/d on improving nutrient digestion by bulls. Also, La Count *et al.* (1995) found that LC administration increased apparent digestibility of lipid, energy, and fatty acids in multiparous Holstein cows administrated carnitine. Also, total volatile fatty acids (VFA) concentrations and molar proportions of propionate tended to increase, and molar proportions of acetate tended to decrease, while ruminal NH_3-N concentrations were higher in lambs fed the LC containing diets (Fernandez *et al.,* 1997).

In the literature, there is lack of information on the effect of LC treatment on volume of various digestive tract compartments. It is difficult however to establish clear and direct effect of LC. These findings may indicate that LC had indirect effect on the anatomical development of the digestive tract segments. The obtained differences in the anatomical characteristics of the digestive tract in this study was almost as absolute values, but most anatomical parameters relative to total stomach compartments or the whole digestive tract was not significant. These differences may be attributed to an effect of LC treatment on reducing feed intake and improving rumen fermentation of lambs during the experimental period without any effects on live body weight of lambs (Mehrez *et al.,* 2015). In this respect, the consumption of roughages elicits an early increase in the growth of the stomach tissue (Warner *et al.,* 1956) and solid feed consumption stimulates rumen morphological development (Warner and Flatt, 1964). (Baldwin *et al*., 2004) reported that less consumption of solid feed by the calves fed milk *ad lib* is associated with poor performance post-weaning, probably because of delayed ruminal development. Also, (Purser and Moir 1966) found a significant positive correlation between empty weight of rumen and sheep weight. In addition, the effect of LC on digestion of feeds in the rumen may affect rate of passage of ingesta and the mechanical effect of feeds throughout different digestive tract segments. This improves ruminal fermentation. Finally, several metabolic changes also occur in the rumen epithelium in concern with morphological development, including decreased glucose oxidation, increased VFA oxidation and increased production of ketone bodies from butyrate (Heitmann, et al., 1987 and Baldwant, et al., 1992). Therefore, the effect of LC may be more pronounced on the histological structure of the ruminal papillae or intestinal villi (unpublished data).

In conclusion, L-carnitine treatment led to some changes in the anatomical structure of lambs, in terms of reducing weight or volume of tissues or contents in reticulo-rumen and small intestine which might influence feed utilization.

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تأثير تجريع الـ - كارنتين على التركيب التشريحي لأجزاء القناة الهضمية في الحملان

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أجريت هذه الدراسة لتقييم تأثير تجريع الـ- كارنتين عن طريق الفم على الصفات التشريحية للأجزاء المختلفة للقناة الهضمية في الحملان النامية. أجريت هذه التجربة في وحدة بحوث الإنتاج الحيواني التابعة لقسم إنتاج الحيوان - كلية الزراعة - جامعة المنصورة خلال الفترة من سبتمبر(أيلول) الى ديسمبر(كانون الأول)٢٠١٤م.

استخدم في هذه التجربة ٩حملان رحماني بمتوسط وزن (٣٣,٩±٠,٦٩كغم) وعمر ١٠شهور ووزعت الحيوانات وفقا لوزن الجسم والعمر ثم وزعت المجاميع الثلاث عشوائيا على ثلاث معاملات . غذيت الحيوانات في المجموعة الأولى (G1) على العليقة القياسية (١٤,٤% بروتين خام). بينما في المجموعة الثانية والثالثة غذيت الحيوانات على نفس العليقة ولكن عوملت بالـكارنتين بالتجريع عن طريق الفم بتركيزين ٣٥٠ملغرام (G2) و ٧٠٠ ملغرام (G3) لكل حيوان في اليوم طول مدة التجربة ٦٣ يوم كفترة تجريبية .

غذيت الحملان على دريس البرسيم (١٤,٦% بروتين خام و٣٨% الياف خام) ومخلوط الاعلاف المركزة (١٤,٥% بروتين خام و ٤,٥ ألياف خام)، وكانت تضبط كمية الاعلاف كل اسبوعين حتى وصلت الى ١,٥ كغم دريس و ١,٢كغم علف مركز في نهاية الفترة التجريبية. في نهاية الفترة التجريبية (٦٣) يوم ذبحت كل الحملان في المجموعات التجريبية. فتحت الذبيحة ونزعت القناة الهضمية مباشرة واغلقت القناة الهضمية بداية من المرئ وحتى فتحة الشرج وذلك لقطع كل جزء على حدة. تم تسجيل وزن أجزاءالقناة الهضمية ممتلئ وفارغ ووزن محتوياتها،

وكذلك تم حساب الحجم ممتلئ وفارغ وحجم المحتويات لكل جزء من اجزاء القناة الهضمية وكذلك قياسات الامعاء. اظهرت النتائج ان الوزن الممتلئ للكرش والشبكية والورقية والمعدة الحقيقية والاعور والمستقيم والقولون والوزن الكلي للمعدة المركبة والوزن الكلي للقناة الهضمية كانت اقل بالمعاملة بالـ -كارنتين.

و كان الوزن الممتلئ للامعاء الدقيقة اعلى معنوياً في المجموعة الاولى عن المجموعة الثالثة بينما المجموعة الثانية لم تختلف عن المجموعة الثالثة. النسبة المئوية للوزن الممتلئ للاعور بالنسبة للقناة الهضمية ككل كان اقل معنوياً في المجموعة الثانية بالمقارنة بالمجموعة الثالثة بينما لم يوجد اختلافات بينه وبين المجموعة الاولى. كان وزن الكرش فارغ اقل معنوية في المجموعة الثالثة عن المجموعة الاولى والثانية .

لم يتأثر الوزن النسبي الفارغ بالنسبة للقناة الهضمية لكل الاجزاء معنويا" بالمعاملة بالـ -كارنتين. وكان وزن محتويات الورقية والامعاء الدقيقة اقل معنوية في المجموعة الثانية والثالثة عن المجموعة الاولى بحوالي ٣٣% و ٣٥% و ٢٤و ٣٥ % على التوالي، كان وزن محتويات الاعور النسبي بالنسبة لمحتويات القناة الهضمية اعلى معنوية في المجموعة الثالثة ومتوسط في المجموعة الاولى واقل في المجموعة الثانية. الوزن الممتلئ والفارغ ووزن محتويات الكرش والشبكية والورقية والمعدة الحقيقية بالنسبة الى وزن المعدة المركبة لم تتأثر بالمعاملة بالـ -كارنتين. الحجم الممتلئ للامعاء الدقيقة و الحجم الفارغ للورقية انخفض معنوياً في المجموعة الثالثة والمجموعة الثانية مقارنة بالمجموعة الاولى بينما حجم المحتويات لم يتأثر بالمعاملة بالـ -كارنتين. لم يكن هناك فروق معنوية بين المجموعات في الحجم الممتلئ الفارغ النسبي لكل الاجزاء بالنسبة الى القناة الهضمية ككل ، بينما حجم المحتويات النسبي للورقية بالنسبة للقناة الهضمية زاد معنوياً في المجموعة الثالثة والثانية. تناقص طول الاعور معنويا وايضا حدث انخفاض معنوي في طول الامعاء الدقيقة وفي طول القولون والمستقيم وبالتالي في طول الامعاء ككل وذلك في المجموعات المعاملة بالـ- كارنتين بالمقارنة بالمجموعة القياسية و لم يكن هناك اختلافات معنوية في محيط اجزاء الامعاء .

ونستخلص في هذه الدراسة ان المعاملة بالـ- كارنتين ادت الى بعض التغيرات في التركيب التشريحي في القناة الهضمية في الحملان حيث نقص كل من حجم ووزن الانسجة و محتوياتها لكل من الكرش والشبكية و الامعاء الدقيقة مما قد ينعكس على معدل الاستفادة من الغذاء.

الكلمات المفتاحية: الحملان، الـ- كارنتين، القناة الهضمية، وزن الأنسجة الطازج، ممتلئ، فارغ، وزن محتويات ،حجم.